Room for Growth:

The Division of the Mathematics and Computer Science Degree Program

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Introduction

Modern society has seen a tremendous shift toward the use of computers in nearly every aspect of the world (Amarel 401). From meeting the needs of the workforce, furthering student education and paving the way for equity in the world, computers have become an integral part of our society (Leddy 2). While many colleges and universities have a Computer Science curriculum in place, they are often structured in a rigid manner, preventing students from expanding their knowledge and technical skills. As a consequence, students may struggle finding employment upon graduation due to the limitations placed on them in the classroom (Shannon 42).

Further, universities often diminish their existing Computer Science department by combining it with a Mathematics department. Though the two departments could be perceived as symbiotic, by encapsulating one department with another, each essentially becomes stifled with little to no room for independent growth ("Origins at Purdue" 6). This paper will address what can be done to alleviate these limitations and what the effects on student success would be if universities were to implement an adaptable, independent computer science program.

Consequently, the aforementioned issues can result in a general lack of diversity in both Computer Science as a department and a field. This lack of diversity is often attributed to an inaccessibility to adequate career-oriented courses, as well as an absence of sufficient faculty or role models to offer support to students (Breda et al. 7). In the following sections, this paper will examine in greater detail what causes the lack of diversity within the computer science field and what universities can do to help close the gap.

Despite the prevalence of computer science in the workforce, there is an obvious gap in the education process of modern computer scientists. The three most essential areas of improvements are relative to the curriculum itself, the basic structure of the department and the diversification of the student body. The following paper will address each issue in detail based on a culmination of current research relevant to each area, as well as expand on the potential beneficial outcomes of reforming an existing Computer Science education model.

Thesis

Despite the prevalence of computer science in the workforce, there is an obvious gap in the education process of modern computer scientists. The three most essential areas of improvements are relative to the curriculum itself, the basic structure of the department and the diversification of the student body

Research Questions

Are there limitations on student success in a collegiate institute that does not have an autonomous and adaptable Computer Science Bachelor program?

What are some of the possible benefits a student might receive from an education in an autonomous and adaptable CS program?

Why is there such a large gap between men and women in technology and what steps can be taken at the collegiate level to address the lack of diversity in both the classroom and the workforce?

Methodology

The following paper presents research to answer the following questions: Are there limitations on student success in a collegiate institute that does not have an autonomous and adaptable Computer Science Bachelor program and if so, what benefits might a student receive from such a program. The second question that is addressed is to determine what some of the root causes for the lack of diversity within the computer science field and possible adjustments are that can be made to address the concern. The following research will discuss methods to improve the structure and curriculum of an existing Computer Science program and address ways to aid in the diversification of the student body.

The research methods in this paper were both qualitative and quantitative. The qualitative research was used to extrapolate the basis of the research questions while the quantitative research was used provide empirical data to support relative arguments. Much of the information reviewed were scholarly articles gathered through the Ebsco data base using key words such as “computer science”, “education”, “growth rates” and “liberal arts school”. Other information was gatherer through library research using title searches such as “technology” and “origins of computer science”. Some of the most pivotal information was collected through collegiate newspapers as well as seminal articles related to the conceptualization of an independent field of computer science.

Some of the research presented was the result of a comparative analysis of curricula between Liberal Arts SUNY schools with Computer Science Departments. This information was collected by reviewing 64 SUNY schools and narrowing the data sample by eliminating all but Liberal Arts schools. After gaining the pertinent data set, the curricula were then gathered by utilizing the university’s academic and course catalogue.

Further research was done using the Student Academic and Demographic Reports from SUNY Purchase's database, to reflect on the student enrollment and completion of the Mathematics and Computer Science degree program from 2009 to 2018. As the degree is a joint program, there are limitations to the data as it is impossible to extrapolate how many students are studying computer science versus mathematics, however it does provide useful information as to the 10-year trend in growth of the joint department.

Additional examination was done on the gender gap within the fields of computer science. Research in this area was found mainly in peer reviewed articles through the Ebsco data base using key words such as "gender gap" and "women in technology". The approach when analyzing this data was correlative as the research studied education and mentorship pertaining to women's success in the technology field. The research also examined the effects of providing positive interventions in the education of young girls and women.

The measure of student success was observed through statistical analysis gathered by the Bureau of Labor as well as through peer reviewed reports on employment trends in the United States. These reports were located through the Ebsco data base utilizing key words such as "success after graduation" "employment" "career in technology". While these studies do not encompass every form of computer science as a career, the study does incorporate a very large data set and can be used to grasp the general trend of student success after graduation.

Literature Review

Redefining the CS Department

As computer sciences gain momentum within society, the need for "considerable modifications in the educational offering of…colleges and universities" has materialized ("Undergraduate Program" 543). Many research institutions have dedicated their work to understanding the deficiencies in the education system as it pertains to the rapidly growing field of computer science. Though research institutions such as the ACM have made multiple proposals for a computer science curriculum, Gibbs and Tucker had pointed out that "recent efforts to revise the definition of computer science as an academic major have not fully addressed the curricular needs" (202). The authors explained that the proposed computer science curriculum was rigid and did little to address the distinct needs of a computer science degree program in a Liberal Arts setting. Liberal Arts colleges and universities "view computer science as an essential discipline within their general academic mission, and… as preparation for a variety of career paths and graduate programs" (Gibbs and Tucker 204).

Gibbs' and Tuckers assertions were emphasized by Amarel, a former computer science professor at Rutgers University, who understood that as the field of computer science can extend into any area of intellectual activity, it must not "grow in isolation, but… actively seek and strengthen intellectual bonds… with other disciplines (391)." Ajwa and Cao agreed with Amarel that computer science is a "dynamic field spanning across many disciplines" and that curriculums must be multifaceted to fulfill the needs students in the computer science field may have (1940).

Amarel cautioned that as "we are now entering a decade where the interface of computer science and society will become universal… It is essential for universities to train people with sufficient depth of knowledge in computer science and with a broad enough vision to see the

potential of computers for the solution of significant problems in society" (401). Understanding the significance of computer science and the implications it could have on society, Gibbs and Tucker proposed a computer science curriculum that is intensive enough to properly train budding computer scientists yet at the same time flexible, in order to promote interdisciplinary learning. By enriching the curriculum to include a multitude of varied courses, students are given the opportunity to diversify and pursue different avenues in the computer science field (Ajwa and Cao 1940).

Additionally, the rapid growth of the computer science industry demands a certain amount of autonomy from other disciplines. While researchers such as Gibbs and Tucker argued that "mathematics…are not separate" (204) and that "mathematics plays an essential role in the development of computer science" (206), others disagreed. Dr. John Rice and Saul Rosen of Perdue University said of combined mathematics and computer science classes that "it is completely unrealistic to teach programming to a mixed class of students" ("History at Purdue" 1). They went on to say that not only would "the establishment of an autonomous Department of Computer Science…be better for its own development", but they suggested that the independent department would lend itself to unlimited research projects and would serve the university as a whole ("Origins at Purdue" 6). While a Computer Science department should cast a wide net to encompass a multitude of career-oriented paths, it should not be dependent on any one specific department other than itself (Amarel 391).

While some researchers, such as Gibbs and Tucker did not recognize the need for autonomous Computer Science departments in educational institutions, Rice and Rosen agreed with Amarel and expounded on the benefits. In the report "History of Computer Science at Purdue University", the authors outline the conception of the first independent Computer Science

department in the United States. They explained that through the separation from the Mathematics department, the Computer Science department "found its identity and matured into one of the strongest departments at Purdue and in the nation" (1). Not only did the department increase student enrollment exponentially, the Computer Science department at Purdue University became a model that many other universities soon emulated (5).

Bridging the Gap

While the issues with curriculum and autonomy are significant concerns, one of the most hotly debated topics in Computer Science is the lack of diversity within the computer science field. Due to its pervasiveness in both academics as well as in the workforce, there has been a vast amount of research done on the topic. A report by the joint National Academies reflected on the lack of diversity, specifically in terms of the absence of women and underrepresented minorities (African Americans and Latino/as). According to the report, women account for as little as 18% of all computer science bachelor's degrees granted and underrepresented minorities as low as 10.2% (93-96).

Though there has been a long-held assumption that the gender gap "is the result of work-life tradeoffs often expected of women" ("The Permanent Detour" 24), new research shows that it is often the lack of female role models or faculty members within the computer science department that exacerbates the gender gap within the field (Breda et al. 1). Leddy agreed with Breda and added that "eradicating…stereotypes about women and technology is also key… A lot of women think that if you're in computer science, that…will stigmatize you" (3).

Although the lack of diversity within the computer science degree is ongoing, recent studies have shown a positive trend in the number of women and underreported minorities

enrolling in undergraduate computer science programs. Jodi Tims et al. reported that "the combined percentage of under-reported minority students… is 20.01%, higher than reported last year (18.1%)" (60). According to data compiled by the ACM-NDC report, "We continue to see enrollment growth in most areas of computing… specifically in Computer Science" (68). Not only has there been overall growth in enrollment, but ethnic diversity in both the student body as well as the faculty had improved over the last year (60).

The National Academies view the lack of diversity not simply as a problem, but rather as an opportunity for departments to grow. The authors stated that "diversity is critical to success in any field. Diversity of perspectives and experiences result in robust thinking and approaches that can help yield solutions and products that meet the needs of a diverse customer base… Diversity is often linked to positive outcomes, such as greater innovation, productivity, and profit" (91).

Through their research, the Academies have determined that the most effective manner to gain diversity within the programs is to be "intentional about the increase" (92) by setting up programs and policies that target the underrepresented students. They have also concluded that utilizing real-world context in the curriculum may help with student retention and success. Other beneficial findings the report offered was to enable students to participate in research programs, provide a curriculum that allows for a multitude of career paths, and have faculty acts as mentors for the students (114).

Student Success

While there are many roadblocks in the development of an effective Computer Science department, and the initial costs of implementing appropriate programs may be steep, the return on investment is immeasurable. According to the U.S Department of Labor, employment of

computer scientist is projected to grow 19% in the next 7 years, which is an exponentially faster growth rate than most other occupations ("Occupational Outlook"). Moreover, the underemployment rate for graduates in Computer Science is far lower than average, with only 18% underemployed 5 years after graduation as oppose to the 35-50% of underemployment of graduates in other fields ("The Permanent Detour" 20). Furthermore, a recent report by the National Academies "identified a massive economic opportunity with increasing the ethnic and gender diversity in the U.S. technology workforce, with the potential to add $470 to $570 billion to the U.S. tech sector and support the creation of jobs and the improvement of products" (91).

As computer science advances and becomes integrated into everyday life, it is essential to facilitate the education of highly trained computer scientist. As the National Academies noted, educating computer scientists in an effective manner has the potential to benefit not only the student, but the economy as a whole (91). By addressing the prevailing obstacles within the education system such as the rigidity of curriculum, need for autonomy and lack of diversity, educational institutions will open the doors for a new generation of highly trained and capable computer scientist.

Analysis

As described in the review of literature, computer science is an ever-evolving field upon which society relies on more heavily every day. While computers are necessary in nearly every profession, there remains pervasive flaws in the educational system that must be addressed to ensure the best education for our future computer scientists. There is a great deal of research that examines the benefits of flexible and autonomous computer science degree programs at the collegiate level and the detriments of not providing students with adequate avenues to explore within the field. Similarly, there has been much scrutiny in the recent years regarding the lack of

diversity within the technology field. While there has been a long-held rationale that women simply had domestic responsibilities and therefore were underrepresented, modern research has proven that to be a fallacy.

While this paper endeavors to relay reliable and comprehensive information, it is important to recognize limitations on the collection of data. Several of the peer review articles were seminal works, which while groundbreaking and credible, may contain some outdated information. Additionally, the research procured through university academic and course catalogues were not verified with the department chairs, nor was there any indication of the date the information had most recently been updated. This paper makes great effort to maintain accuracy throughout and will acknowledge any limitations.

While there may be correlations between the success of a student upon graduation and the computer science program they graduated from, there is a lack of research that directly relates a student's achievement to their degree program. Research does indicate that developing a flexible and adaptable course curriculum for a computer science program can further a student's chance to succeed by presenting the student with a myriad of career options to pursue. Additionally, the growth of the department was shown to increase when the department was fully independent, with its own department head and faculty devoted specifically courses. The research also demonstrates that the expansion of the computer science department may also have a positive effect on the diversity within the classroom. By providing students with more choices and faculty to act as mentors, the gender gap within the computer science field can be diminished.

The first independent Computer Science department in the United States was formed out of necessity. The President at Purdue, along with the head of the Mathematics department understood that computer science as a field was growing at exponential rates and in order to meet

the demand for more computer scientists, they had to allow the computer science department to grow along with that demand ("Origins at Purdue" 6). The same need is apparent today and schools are emulating the actions of Purdue University. In 2018, Emory College, a leading research university, decided that it was time to separate their Mathematics and Computer Science department into two distinct departments. According to James Nagy, the department chair of Mathematics, "The structure of separate departments allows us to better highlight our outstanding accomplishments, which in turn can only make Emory more of a go-to place for the best new undergraduate and graduate students." Vaidy Sunderam, the new department chair of Computer Science agreed with Nagy and stated that "…computer science is data centric, on the cutting edge, and now we can grow even more in that domain" ("Grow by Becoming Separate" 1). Emory College, like Perdue came to the realization that they must be willing to expand to keep up with the ever-growing field of computer science.

Analytical research was done using the Student Academic and Demographic Reports from SUNY Purchase's database. The research reflected on the slow growth of the student body in the combined Mathematics and Computer Science degree program at SUNY Purchase. As the degree is a joint program, it is difficult to deduce the precise number of students studying computer science as oppose to mathematics. Bearing this deficiency in mind, the overall growth of the department in the last 6 years, as compared to the average growth rate of computer science departments in the US as found in the "Sixth Annual Study of Non Doctoral-Granting Departments in Computing" is almost imperceptible.

Furthermore, a comparison study was done of the computer science curricula of 8 Liberal Arts SUNY schools. One university, SUNY Geneseo, did not offer any form of a Computer Science Degree and a second, SUNY Purchase, had a joint Mathematics and Computer Science

department. The remaining 6 schools all had standalone Computer Science departments that were actively engaging students in internships and collegiate level coding competitions with other universities. Between the 8 schools, the comparison showed an extreme disparity not only between the number of courses offered, but the content of the courses dedicated to computer science. The universities that had an independent program each offered upwards of 20 courses dedicated to a wide range of computer science courses. The one university with the joint Mathematics and Computer Science program offered 10 courses with a far less extensive range of subjects, nor were any internships available to students.

Despite the fact that research indicates a connection between autonomous Computer Science departments and growth in curriculum, there is a need for further ongoing statistical analysis to be done on the growth rate of the student population. Though more research is needed, it is important to recognize that the education of computer scientists should not have limitations set upon it. For the next generation of computer scientists to succeed, they must have a well-rounded education with courses that allow them to grasp the abundance of applications their chosen field can have. A versatile computer scientist can make incredible contributions to the rapidly growing field of technology. In order to provide students with the courses they require, an independent department is shown to be a catalyst for a department's growth.

According to The National Academies, diversity of perspective and experience is critical to the development and success in any field (91). The question then remains why computer science is among the least diverse fields in the United States. Though the field of computer science began with woman holding the vast majority of positions, that ratio has changed drastically, with women accounting for an estimate of only 23 percent of the tech workforce (The National Academies 91). The pervading explanation for the severe disparity boils down to the

lack of mentorship as well as the misguided cultural ideology that women do not belong in technology. The research suggests that the way to combat these issues is to provide female students with dedicated mentors, whether they be faculty or other students, to help guide them to realize their potential abilities. Mentors can also help female students understand that the underrepresentation of women can only end through the representation of women. Furthermore, research indicated that providing students with internship opportunities not only gives the students real-world experience, it is a viable method to increase the representation of women in the workforce.

Conclusion

Many researchers agree that there is room for improvement in the education of modern computer scientist and that there exists a substantial gender gap in the technology field. However, not all research agrees that there is a need for an adaptable curriculum or autonomous departments. Researchers such as Gibbs and Tucker advocate that computer science should be taught with a strong mathematical emphasis. As logical as their proposition may have seemed when computer science was a small and somewhat obscure field, most modern research emphatically disagrees. Due to the extensive nature of the field of computer science, researchers such as Amarel, Rice and Rosen determined that computer science curricula should be multifaceted and independent in order to keep up with the needs of society.

Furthermore, most researchers agree that providing students with multiple avenues for computer science education can not only increase student retention, but can attract a more diverse student body, thereby bridging the gender gap which is so prevalent in the computer science field. As the National Academies found, providing multiple pathways for students and

including real world learning, such as internships, are some of the best practices for retention and diversification of the student body (National Academies 114).

In conclusion, while research gives support for an adaptable, diverse and independent Computer Science program, there are many variables that might stand in the way of attaining such a department. One to consider, would be the financial roadblocks that is to be expected from the creation of a new department warranting the support of an increased number of faculty members. One might also consider, that if a Computer Science department is doing reasonably well as a joint degree, is there cause to upend it and redevelop it? While studies done on the employability and success of graduates from strong computer science programs indicate that the expenditure is well worthwhile, further research is needed to formulate a realistic approach on how a school could successfully commence on making these changes.

Works Cited

"Academic Reports." *Purchase College Collaboration Center*, collaborate.purchase.edu/OIRreports/Academic%20Profiles/Forms/AllItems.aspx.

Ajwa, Iyad A., and Paul Y. Cao. "Enhancing Computational Science Curriculum at Liberal Arts

Institutions: A Case Study in the Context of Cybersecurity." *International Conference on Computational Science 2016*, vol. 80, 2016, pp. 1940-1946., www.sciencedirect.com/science/article/pii/S1877050916309978.

Amarel, Saul. "Computer Science: A Conceptual Framework of Curriculum Planning." *Communications of the ACM*, vol. 14, no. 6, 1971, pp. 391- 401.

"Assessing and Responding to the Growth of Computer Science Undergraduate Enrollments." *The National Academies of Sciences, Engineering, and Medicine*, 2018, pp. 91- 114.

Breda, Thomas, et al. "Can Female Role Models Reduce the Gender Gap in Science?" *Paris Jourdan Sciences Economiques*. 2018, pp. 1-7, halshs.archives-ouvertes.fr/halshs-01713068/document.

Christine Shannon. "Computer Science and the Liberal Arts." *Association of American Colleges and Universities*, 2010, pp. 42-45.

Gibbs, Norman E., and Allen B. Tucker. "A Model Curriculum for A Liberal Arts Degree in Computer Science." *Communications of the ACM*, vol. 29, 1986, pp. 202-210.

Leddy, Chuck. "Closing the Gender Gap in Computer Science." *Harvard School of Engineering and Applied Sciences*. 2014, pp. 1-4, www.seas.harvard.edu/news/2014/02/closing-gender-gap-in-computer-science.

"Occupational Outlook Handbook, *Bureau of Labor Statistics U.S. Department of Labor*, Computer and Information Research Scientists." 2018,

www.bls.gov/ooh/computer-and-information-technology/computer-andinformation-research-scientists.htm.

"The Permanent Detour: Underemployment's Long- Term Effects on the Careers of College Grads." *Burning Glass Technologies and Strada Institute for the Future of Work*, 2018, pp. 8-30., www.burning-glass.com/wp-content/uploads/permanent_detour_underemployment_report.pdf.

Rice, John R., and Saul Rosen. "History of the Computer Sciences Department at Purdue University." Purdue University Department of Computer Science Technical Reports. 1990, pp. 1-150, docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1005&context=cstech.

Rice, John R., and Saul Rosen. "Origins of Computing and Computer Science at Purdue University." *Purdue University Department of Computer Science Technical Reports*, 1990, pp. 31-44, docs.lib.purdue.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=1006&context=cstech.

"Student Academic and Demographic Reports." *Purchase College Collaboration Center*, collaborate.purchase.edu/OIRreports/Student%20Academic%20and%20Demographic%20Reports/Forms/AllItems.aspx.

"Student Success Reports." *Purchase College Collaboration Center*,

collaborate.purchase.edu/OIRreports/Student%20Success%20Reports/Forms/AllItems.aspx.

SUNY Fredonia. “2018-2019 Catalog Undergraduate and Graduate Programs.” fredonia.smartcatalogiq.com/en/2018-2019/Catalog.

SUNY Old Westbury. “Undergraduate Catalog 2018-2020.” www.oldwestbury.edu/sites/default/files/documents/Catalogs/2018-20/undergrad catalog-18-20.pdf.

SUNY Oneonta. “Course Descriptions.” 2019, catalog.oneonta.edu/content.php?catoid=7&navoid=330.

SUNY Oswego. “2018-2019 Undergraduate Catalog.” catalog.oswego.edu/preview_program.php?catoid=38&poid=4567.

SUNY New Paltz. “Undergraduate Catalog 2018-2019.” 28 Sep. 2018, www.newpaltz.edu/media/undergraduate--catalog/2018 2019%20Undergraduate%20Catalog%20New%20Paltz%209-28-18.pdf.

SUNY Plattsburgh. “2018-2019 Catalog.” 1 May 2018, catalog.plattsburgh.edu/mime/media/5/753/2018-2019-Plattsburgh+College+Catalog.pdf.

SUNY Purchase. “Purchase College Catalog 2016-18.” 29 Aug. 2016, www.purchase.edu/live/files/1038-2016-18-college-catalog.

Tims, Jodi, et al. “ACM-NDC Study 2017–2018: Sixth Annual Study of Non

Doctoral-Granting Departments in Computing." *ACM*, 2018, pp. 57-60, www.acm.org/binaries/content/assets/education/acm-ndcstudy2017-2018.pdf.

"An Undergraduate Program in Computer Science." *Communications of the ACM*, vol. 8, no. 9, 1965, pp. 543-552.